Class R, Monophonic Audio Power Amplifier. Fixed x32 gain, built-in boost module, 3 anti-breaking modes, AB/D switching function, 11W constant output power

Summary description

CS83601E is a class R audio power amplifier with built-in boost module with anti-breaking sound function (to avoid burning the speaker coil). Built-in boost module R type structure integrates two modes: class D and class AB. It can provide constant power up to 11W for a load of 2Ω.

The design of the switchable mode of class AB to class D minimizes the interference of the power amplifier in the FM frequency subsystem. The low FM interference and the power output provided within the power supply voltage range of one lithium battery make CS83601E become the best choice of portable speaker equipment, especially loudspeaker products.

The fully differential architecture of CS83601E and extremely high PSRR, effectively improve the ability of CS83601E to suppress RF noise, even without filter.

The PWM modulation structure without filter and the built-in boost module as well as CS83601E use of a proprietary AERC (Adaptive Edge Rate Control) technology adopted by, greatly reduce EMI interference within the full audio bandwidth range. So, for 60 cm audio cable length, the EMI interference is more than 20dB unde r the FCC standard.

In addition, CS83601E has built-in overcurrent protection, short circuit protection and overheat protection which effectively protect the chip from being damaged under abnormal working conditions.

CS83601E provides a tiny **ESOP10L** package for customers to choose. Its rated operating temperature range is -40°C to 85°C.

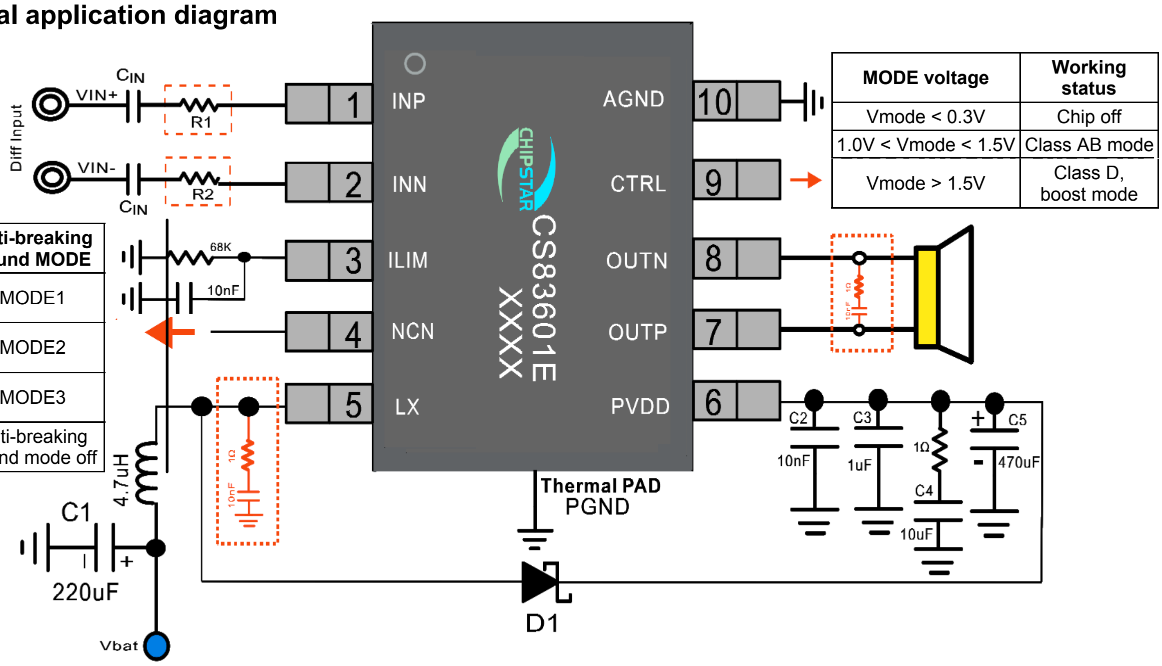
Features

- Built-in boost module R-type structure, that integrates two modes: class D and class AB. (switching to class AB can reduce the interference of power amplifier to FM in the system.)
- Output Power (P0 at 10% THD+N, V_{BAT} = 3.7V, D-MODE, NCN=OFF): 11W (RL = 2 Ω), 6.6W (RL = 4 Ω)
- Excellent "pop-noise" suppression ability
- Operating voltage range: 2.5V to 5.5V
- Built-in fixed gain (x32)
- Power adaptive function
- Built-in anti-breaking sound module
- Class-D structure without filtering
- 80% efficiency (70% efficiency for 2 Ω load)
- High power supply rejection ratio (PSRR): 70dB at 217Hz
- Soft start-time: 100ms
- Quiescent current: 15mA
- Low shutdown current: < 0.1μA
- Overcurrent protection, short circuit protection and overheating protection
- Lead-free package that meets Rohs standard

Applications:

- Portable bluetooth speaker
- Backpack Speaker/Trolley Speaker

Typical application diagram

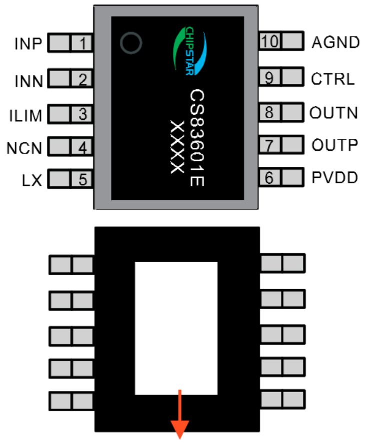


NCN status	Anti-breaking sound MODE
Directly grounded	MODE1
50 kΩ to ground	MODE2
100 kΩ to ground	MODE3
float	Anti-breaking sound mode off

MODE voltage	Working status
Vmode < 0.3V	Chip off
1.0V < Vmode < 1.5V	Class AB mode
Vmode > 1.5V	Class D, boost mode

Remarks: • The Schottky type of D1 is SS34. When the output load is 2Ω, D1 is selected as SS54, and a 1Ω+10nF filter circuit
to the ground is added to the LX terminal (the red dotted line in the application diagram).

- The filtering of the virtual boxes in the figure (1Ω+10nF) can be reserved for design.
- Please select speakers with impedance load greater than 2Ω to avoid chip over-temperature protection.
- The R1, R2 in the red box in the figure are reserved for control of the input resistance (Note the CS83601E has a built-in x32 gain and the internal integrated input resistance is 22.5 kΩ. The feedback resistance is 720 kΩ.
- The bottom heat sink of CS83601E is defined as PGND pin.



PIN11: Bottom heat sink

PIN	Description	Input/Output	Features
1	INP	INPUT	Normal phase audio input
2	INN	INPUT	Inverted audio input
3	ILIM	INPUT	Inductor peak current control pin
4	NCN	INPUT	Anti-breaking sound control pin
5	LX	INPUT	Switch pin (connected to external inductor)
6	PVDD	Pow. supply	Power supply
7	OUTP	OUTPUT	Normal phase audio output
8	OUTN	OUTPUT	Inverted audio output
9	CTRL	INPUT	Off / AB / D modes control pin
10	AGND	Ground	Analogic ground
11 Thermal PAD	PGND	Ground	Power ground

Absolut Maximum Ratings[1]

Parameter	Description	Value	Unit
V_{Bat}	Power supply voltage without input signal	6	V
V_I	Input voltage	-0.3 to V_{BAT}+0.3	V
T_J	Working temperature range	-40 to 150	℃
T_{SDR}	Pin temperature (soldering for 10 seconds)	260	℃
T_{STG}	Storage temperature range	-65 to 150	℃

Recommended working environment

Parameter	Description	Value	Unit
V_{Bat}	Power supply voltage	2.5~5.5	V
T_A	Ambient temperature range	-40~85	℃
T_j	Junction temperature range	-40~125	℃

Thermal effect information

Parameter	Description	Value	Unit
θ_{JA}	Package thermal resistance – Chip-to-ambient thermal resistance	50	℃/W
θ_{JC}	Package thermal resistance – Chip to package surface thermal resistance	10	℃/W

Ordering information

Product number	Package form	Device identification	Package Size	Tape width	Quantity
CS83601E	ESOP10L (Extrem Small Outline Package)		TUBE		100 units

ESD range

ESD range HBM (Human Body Electrostatic Model) -- ±4kV

ESD range MM (Machine Electrostatic Mode) --±400V

[1] 1. The above parameters are only the limit values of the device's work. It is not recommended the working conditions of the device to exceed this limit value, otherwise it will affect the reliability and life of the device, and even may cause permanent damage.

2. The place of the CS83601E on the PCB board needs to have a good heat dissipation design. The heat sink at the bottom of the CS83601E has to connect to the heat dissipation area of the PCB board and connect to the ground through a via.

Electrical parameters (T_A= 25ºC, unless otherwise specified)

Parameter	Description	Test conditions	Min.	Typical	Max.	Unit
$\lvert V_{OO} \rvert$	Output offset voltage	Δ_{VIN}=0V, Av=2V/V V_{BAT}=3.0V to 5.0V		5	25	mV
PSRR	Power Supply Rejection Ratio	V_{Bat} =2.5V to 5.5V,217Hz		-70		dB
CMRR	Common Mode Rejection Ratio	Input pins shorted, V_{Bat}=2.5V to 5.5V		-72		dB
I_{DD}	Quiescent current	V_{Bat} =3.7V, no load no filter		15		mA
I_{SD}	Shutdown current			0.1		μA
$r_{DS(ON)}$	Source to drain ON resistance	V_{Bat}=3.7V		220		mΩ
		V_{Bat}=5.0V		200		
$f_{(SW)}$	Class D modulation frequency	V_{Bat} =2.5V to 5.5V		350		KHz
Rin	Built-in input resistor			22.5		KΩ
Rf	Built-in feedback resistor			720		KΩ

BOOST module electrical parameters (T_A = 25ºC V_{Bat}= V_{MODE} = 3.7V, unless otherwise specified)

Parameter	Test conditions	Min.	Typical	Max.	Unit
Input voltage, V_{Bat}		2.5		5.5	V
Undervoltage protection threshold	V_{Bat} Rising		2.0		V
Switching frequency			350		KHZ
Maximum duty cycle		85			%
Switching-on current	V_{Bat}= 3.7V, duty cycle = 70%		6.0		A
Switching-on resistence			100		mΩ
Switching-off leakage current	V_{LX} = 7.5V, V_{MODE} = 0			15	uA
Heat protection temperature limit			160		°C
Thermal hysteresis			40		°C

Working characteristics (T_A = 25ºC, R_L = 4Ω)

Parameter	Description	Test conditions	Min.	Typical	Max.	Unit
P_O	Output power, Class D mode (NCN=OFF)	Vbat=3.7V,THD=10%,f=1KHz,RL=2Ω		11.0		W
		Vbat=3.7V,THD=1%, f=1KHz,RL=2Ω		9.0		
		Vbat=3.7V,THD=10%,f=1KHz,RL=3Ω		8.20		
		Vbat=3.7V,THD=1%, f=1KHz,RL=3Ω		6.50		
		Vbat=3.7V,THD=10%,f=1KHz,RL=4Ω		6.60		
		Vbat=3.7V,THD=1%, f=1KHz,RL=4Ω		5.30		
THD+N	Total harmonic distortion + noise	Vbat=3.7V,Po=3.0W, f=1KHz,RL=4Ω		0.07		%
η	Efficiency	Vbat=3.7V,Po=4.5W, f=1KHz,RL=4Ω		80		%
t_{ST}	Chip start-time			100		ms
P_O	Output Power, Class AB mode	V_{DD} =5.0V,THD=10%,f=1KHz,RL=4Ω		3.00		W
		V_{DD} =5.0V,THD=1%, f=1KHz,RL=4Ω		2.42		
		V_{DD} =5.0V,THD=10%,f=1KHz,RL=2Ω		4.80		
		V_{DD} =5.0V,THD=1%, f=1KHz,RL=2Ω		3.84		
THD+N	Total harmonic distortion + noise	V_{DD} =5.0V,Po=1.0W, f=1KHz,RL=4Ω(AB mode)		0.2		%
		AB mode =3.6V,Po=0.5W, f=1KHz,RL=4Ω		0.3		

T_A=25ºC, R_L=4Ω pure resistance, class D MODE 1, C_{OUT}=470μF, f=1KHz, NCN directly grounded

Parameter	Description	Test conditions	Value	Unit
P_O	Output Power	V_{Bat}=3.6V,Vpp=300mV,RL = 4 Ω	4.25	W
		V_{Bat}=3.6V,Vpp=300mV,RL = 2 Ω	7.00	
THD+N	Total harmonic distortion	V_{Bat}=4.2V,Vpp=300mV,NCN MODE1	0.40	%
		V_{Bat}=3.6V,Vpp=300mV,NCN MODE1	0.40	
T_{at}	Anti-breaking sound start time		50	ms
T_{rl}	Anti-breaking sound release time		300	ms

T_A=25ºC, R_L = 4Ω pure resistance, class D MODE 2, C_{OUT}=470μF, f=1KHz, NCN grounded through 50KΩ

Parameter	Description	Test conditions	Value	Unit
P_O	Output Power	V_{Bat}=3.6V,Vpp=300mV,RL = 4 Ω	4.00	W
		V_{Bat}=3.6V,Vpp=300mV,RL = 2 Ω	6.50	
THD+N	Total harmonic distortion	V_{Bat}=4.2V,Vpp=300mV,NCN MODE2	0.30	%
		V_{Bat}=3.6V,Vpp=300mV,NCN MODE2	0.30	
T_{at}	Anti-breaking sound start time		4	ms
T_{rl}	Anti-breaking sound release time		2	s

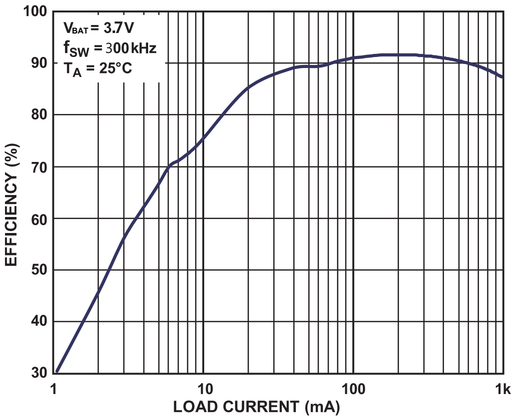
T_A=25ºC, R_L = 4Ω pure resistance, Class D MODE 3, C_{OUT}=470μF, f=1KHz, NCN grounded through 100KΩ

Parameter	Description	Test conditions	Value	Unit
P_O	Output Power	V_{Bat}=3.6V,Vpp=300mV,RL = 4 Ω	5.40	W
		V_{Bat}=3.6V,Vpp=300mV,RL = 2 Ω	9.30	
THD+N	Total harmonic distortion	V_{Bat}=4.2V,Vpp=300mV,NCN MODE 3	1.80	%
		V_{Bat}=3.6V,Vpp=300mV,NCN MODE 3	1.80	
T_{at}	Anti-breaking sound start time		50	ms
T_{rl}	Anti-breaking sound release time		75	ms

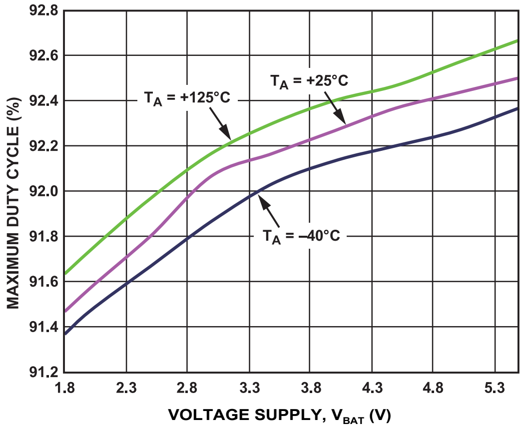
* TRANSLATOR'S NOTE: *"It can provide constant power..."* This sentence applies ONLY to D class mode. In this mode, the booster provides a constant supply voltage of 7.5V to the amplifier for any value of the V_{BAT} voltage.

BOOST mode - Typical characteristic curves TA=25°C, RL = 4 Ω

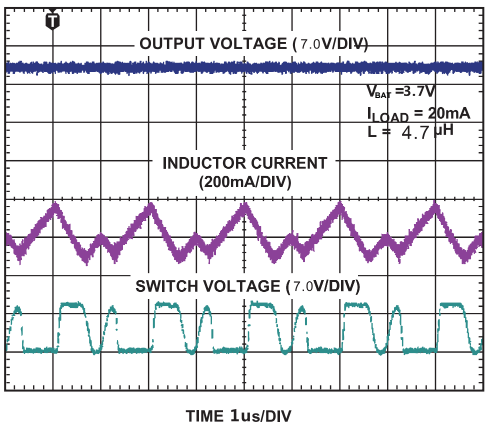
Efficiency vs. Load Current, V_{BAT} = 3.7 V, f_{SW} = 300KHz



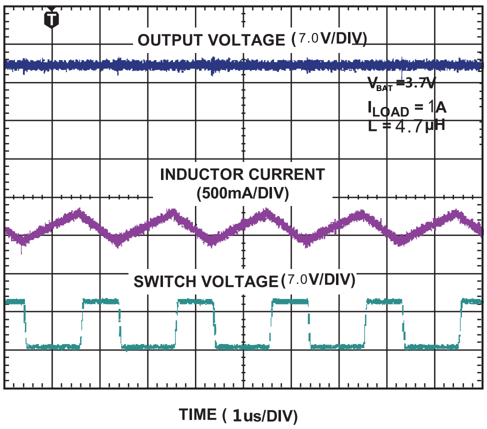
Maximum Duty Cycle vs. Input Voltage, f_{SW} = 300KHz



Switching Waveform in Discontinuous Conduction Mode

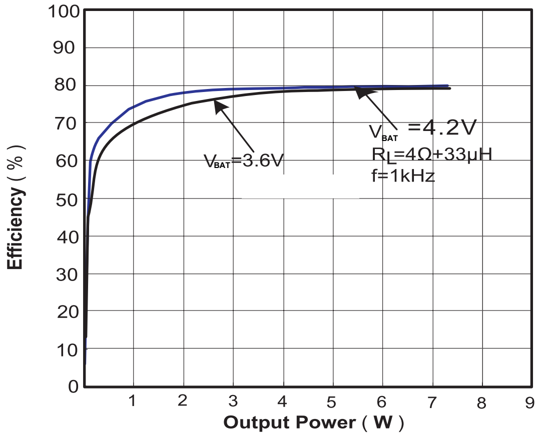


Switching Waveform in Continuous Conduction Mode

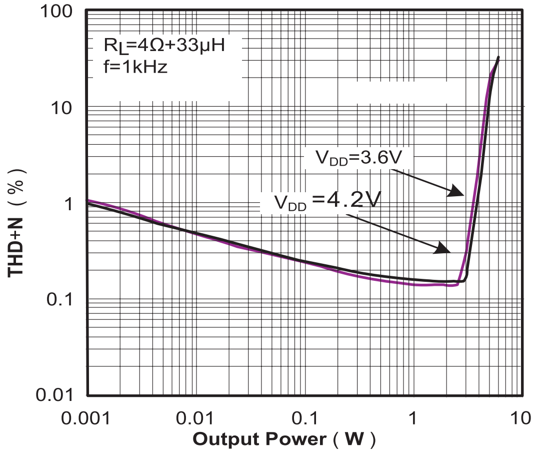


Class D mode - Typical characteristic curve T_A=25°C, RL = 4 Ω

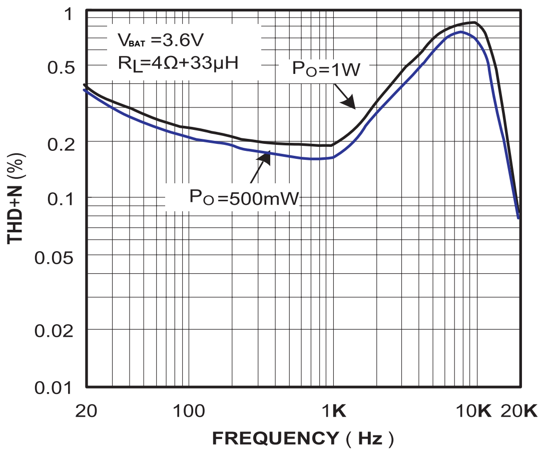
EFFICIENCY vs OUTPUT POWER



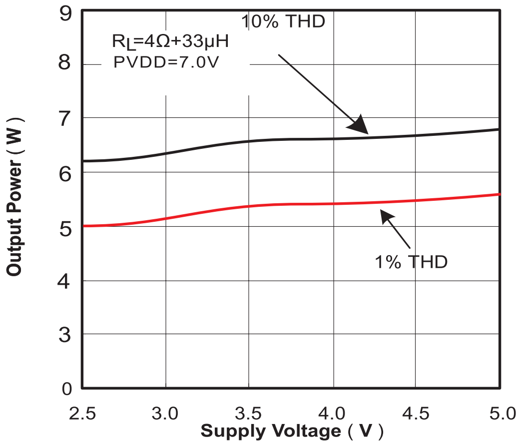
THD+N vs OUTPUT POWER



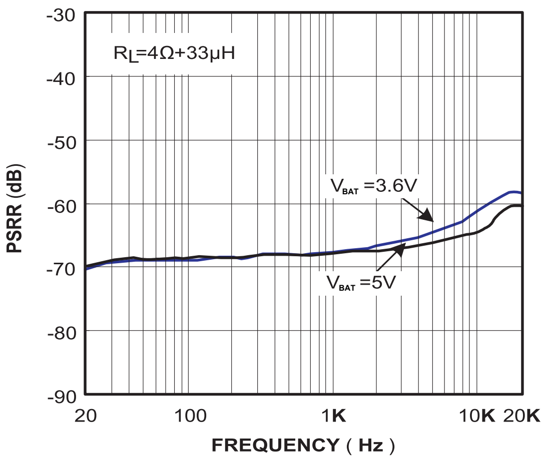
THD+N vs FREQUENCY



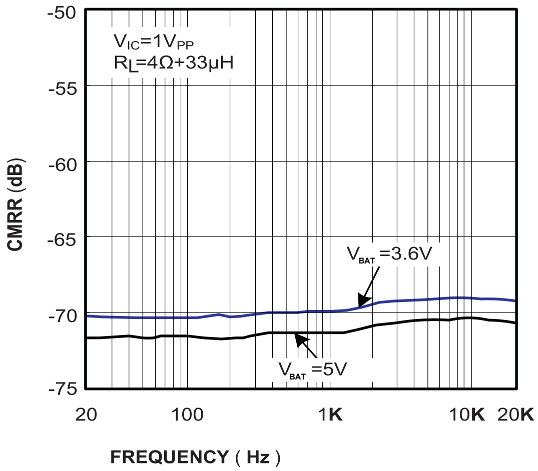
OUTPUT POWER vs SUPPLY VOLTAGE



PSRR vs FREQUENCY



CMRR vs FREQUENCY



CS83601 Application Notes

Working Modes Control Setting

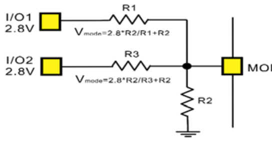
CS83601E has three working modes: (i) the chip is turned off; (ii) class AB mode, and (iii) class D, boost mode.

MODE voltage	Vmode <0.3V	1.0V<Vmode<1.5V	Vmode > 1.5V
Working status	Chip off	Class AB mode	Class D, boost mode

Based on the control method in the above table, the actual use can be set as follows according to the system.

If the main controller's I/O control voltage is 2.8V, as shown in the fig. below, with the help of two I/Os and a voltage divider which realize the switching of three working states.

$V_{mode} = 2.8*R_2/(R_1+R_2)$
$V_{mode} = 2.8*R_2/(R_3+R_2)$



When I/O1 and I/O2 are low, the CS83601E chip is turned off.

When I/O1 is high and I/O2 is left floating, selecting an appropriate R3/R2 so that V_{MODE} is between 1.0-1.5V, CS83601E enters in class AB mode.

When I/O1 is left floating and I/O2 is high level, selecting an appropriate R3/R2 so that $V_{MODE} > 1.5V$, CS83601E enters in the class D mode.

The absolute values of R1, R2 are determined by an acceptable power consumption (MODE itself does not require driving current).

Gain

The built-in feedback resistance of CS83601E is 720KΩ and the built-in input resistance is 22.5KΩ. CS83601E is a fixed gain of x32. For a gain less than x32, the actual value is calculated as: Gain=720KΩ/(22.5KΩ+R_{IN}).

Input capacitance, Cin

A high-pass filter is formed between the input resistance and the input capacitance. The frequency is as follows:

$$f_C = \frac{1}{2\pi(Rin+22.5)C_{in}}.$$

The value of input capacitance is very important, and it is generally accepted that it directly affects the low level of the circuit.

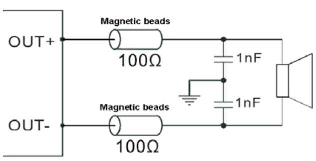
Frequency performance

Speakers in wireless phones are usually not very good for low frequency signals. In response, you can select a relatively large f_c in the application, to filter out the 217Hz noise.

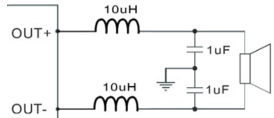
Incoming interference

Good matching between the capacitors improves the overall performance of the chip and Pop&Click suppression is helpful, so the selection accuracy has to be 10% or beter for capacitors.

Inductance, magnetic beads and capacitance of CS83601E module should be tested with a magnetic bead filter under various conditions such as high power and long output load lines. The CS83601E module must pass the FCC, class B test. The type and specification of magnetic beads can be selected according to actual use, as shown below:



If the amplifier is used in a system with harsher noise requirements, the output can be connecting through an LC filter. The relevant parameters of the filter are as follows:



Schottky's choice

The Boost part of CS83601E uses non-synchronous rectification, which requires an external Schottky diode.

Schottky diodes have a great influence on the overall performance of IC and an unappropriate selection may affect the whole machine efficiency, and even can produce a large reverse overshoot voltage at the LX terminal, which will cause the IC to burn out.

The best option we recommend is SS54. But pay attention: the connection from Schottky to inductor and from the output filter capacitor to PVDD should be as short as possible. Improper wiring will increase the overshoot and ringing of the LX terminal, affect EMI and even burn the IC.

The choice of inductance

Inductance has a great influence on the performance of CS83601E. It is recommended to use it according to many considerations, such as ripple stability. Use a 4.7uH inductor and its DCR should be small enough for saturation with a current of 6A or more.

Efficiency

The switching mode of the output transistor determines the high efficiency of the Class R amplifier. In a class R amplifier, the output transistor is like a current adjustment switch, and the extra power consumed during the switching process is basically negligible. The power loss related to the output stage is mainly the IR produced by the on-resistance of the MOSFET as well as the power supply current. After the boost is started, the efficiency of the CS83601E can reach 75%.

Circuit protection

In the application process of CS83601E, when the output pin of the chip is shorted to the power supply or ground, or the short circuit between the outputs occurs, the overcurrent protection circuit will shut down the chip to prevent the chip from being damaged. After the short-circuit fault is eliminated, CS83601E automatically resumes work.

The chip will also be shut down when the chip temperature is too high. After the temperature drops, CS83601E can continue to work normally.

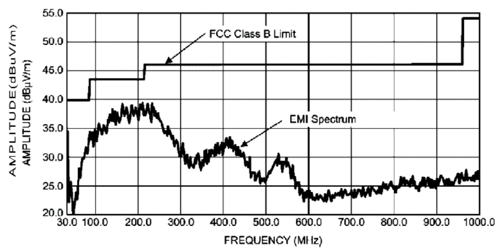
When the power supply voltage is too low, the chip will also be shut down. After the power supply voltage is restored, the chip will start again.

Pop & Click suppression

The CS83601E has a built-in proprietary timing control circuit to achieve comprehensive Pop & Click suppression, which can effectively eliminate the transient noise that may occur when the system operates powered on, powered off, wakeup or shutdown operations.

EMI characteristics

Cs83601 E uses proprietary AERC (Adaptive Edge Rate Control) technology, which greatly reduces EMI interference within the full audio bandwidth range. For 60cm audio lines, it has a margin of more than 20dB under the FCC standard (as shown in the figure bellow).



CS83601E EMI Spectrum

NCN mode

In audio applications, factors such as excessive input signal or battery voltage drop will cause the output signal of the audio power amplifier to be distorted, and the overloaded signal may cause permanent damage to the speaker. This unique NCN function of CS83601E can detect the broken sound distortion of the output signal of the amplifier and automatically adjust the system gain to keep the output audio signal round and smooth, which not only effectively avoids the damage to the speaker caused by the high-power overload output, but also bring more comfortable listening enjoyment.

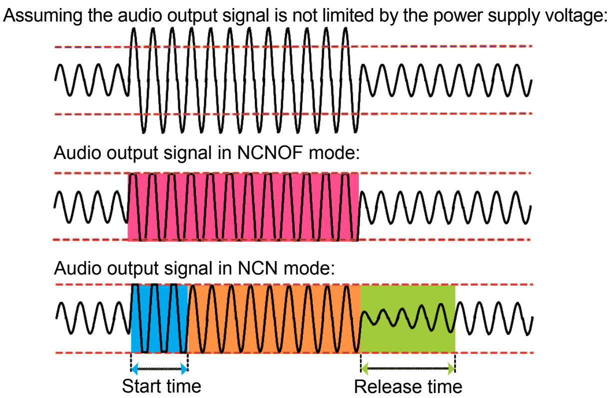
CS83601E provides four NCN working modes and non-breaking sound modes for users to choose: M1, M2, M3 and NCNOFF, and you can enter five modes by setting the different states of the NCN pin.

-Start Time (Attack Time): the time from the occurrence of the broken sound distortion to the completion of the automatic gain adjustment of the system.

-Release Time: the time interval from the disappearance of the broken sound distortion, to the complete exit of the gain reduction state of the system.

Set the start time and release time of M1, M2, M3 and, NCNOFF mode through the NCN pin status, as shown in the following table:

NCN status	Anti-breaking sound mode	Start time	Release time
To ground	MODE 1	50 ms	300 ms
50k to ground	MODE 2	4 ms	2s
100k to ground	MODE 3	50 ms	75 ms
Float	anti-breaking sound off	–	–



Current limit and soft-start function

Setting a pull-down resistor and a capacitor to ground through the I_{LIMIT} pin, can limit the peak current of the BOOST inductor and realize the soft-start function of the power supply.

The following table lists the effective values of soft-start time and inductor current under different resistance and capacitance conditions for reference.

Inductance	Rlim	Power soft-start			Effective value of I_L current
		C=10nF	C=100nF	C=220nF	
	100k	1.8 ms	18 ms	36 ms	5.0 A
4.7 µH	82k	1.7 ms	17 ms	34 ms	4.0 A
	68k	1.6 ms	16 ms	32 ms	3.0 A
	56k	1.5 ms	16 ms	32 ms	1.5 A

PCB board design steps and points

Vbat terminal capacitance

The CS83601E integrates a voltage stabilizing circuit, so there is no need to supply power to the CS83601E through Vbat, and there is no need for a patch debrowning capacitor, just connect the inductor directly.

But generally we recommend adding at least one energy storage electrolytic capacitor to Vbat, because the booster power supply and power amplifier both obtain electricity from Vbat.

The 220µF electrolytic capacitor helps to make the battery voltage more stable, reduce interference to other ICs on the system, and also help. To improve the low-frequency transient response of the CS83601 printing spoon, it also helps to reduce EMI.

PVDD terminal capacitance

The PVDD of CS83601E is actually the output of the boost power supply and the power input of the built-in power amplifier module. Therefore, the filter decoupling capacitor is necessary.

We require two sets of capacitors, one set is decoupling capacitors composed of 1µF + 10µF, and another set is the filter electrolytic capacitors of 470µF.

1 uF + 10uF chip capacitors should be placed as close as possible to the chip pins.

A filter capacitor of 470 uF is also necessary (it is recommended to use high-frequency and low-resistance electrolytic capacitors, which can effectively improve efficiency and reduce voltage ripple). A capacitor that is too small will cause the output voltage of the BOOST module to oscillate.

The capacitance of the PVDD terminal has a great influence on the performance of the CS83601E. For details, please refer to the PCB design guide or contact the original factory engineer.

Input audio GND

The CS83601E is a differential input. When the audio source is also a differential output, the CS83601E can shield interference well, and there is no need to worry too much about the introduction of ground loop noise. However, when the audio source is a single-ended output, attention should be paid to shielding the introduction of a ground loop noise.

Since the characteristics of each system and main control or DAC are different, should pay attention.

Generally, it is recommended to ensure that there is no potential difference between the reference ground of the audio signal and the reference ground of the CS83601E, without signal input through the capacitor grounding pin (or as far as possible place).

PCB design

Step 1: focus on laying out the red part of the lines.

The wiring of inductor L1, Schottky diodes D1, D2 and capacitors C1, C2, C3 is required to be as short as possible and placed as close to the chip as possible. It is best to arrange the inductors, diodes, and capacitors in a straight line.

Step 2: Arrange the power cord and ground wire in the yellow part.

1. The connection between the power supply and the inductor L1 is required to be as thick as possible to reduce the connection current.

2. The connection between the ground wire and the chip heat sink is required to be as thick as possible to reduce the connection resistance.

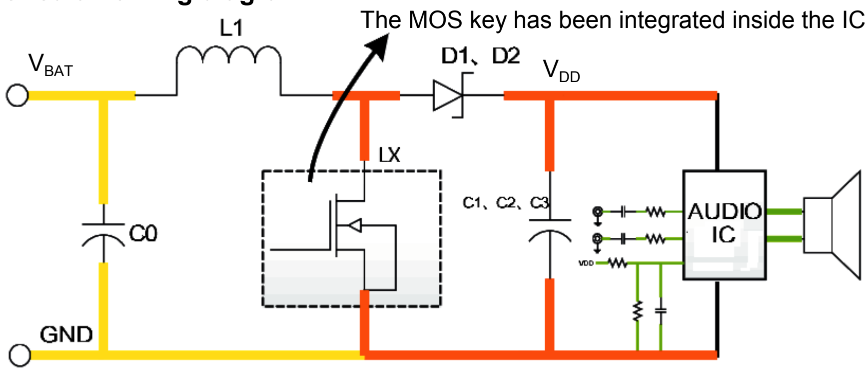
3. There should be as many ground aria around the chip and the cathode of capacitor C1 as possible.

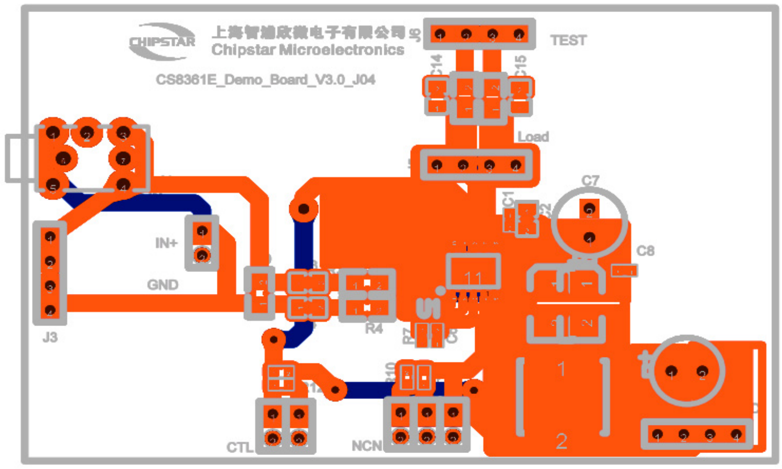
Step 3: Lay out the other lines in the green part of the non-key.

1. Audio input signal 1#, 2# feet parallel walking line. Length is not limited.

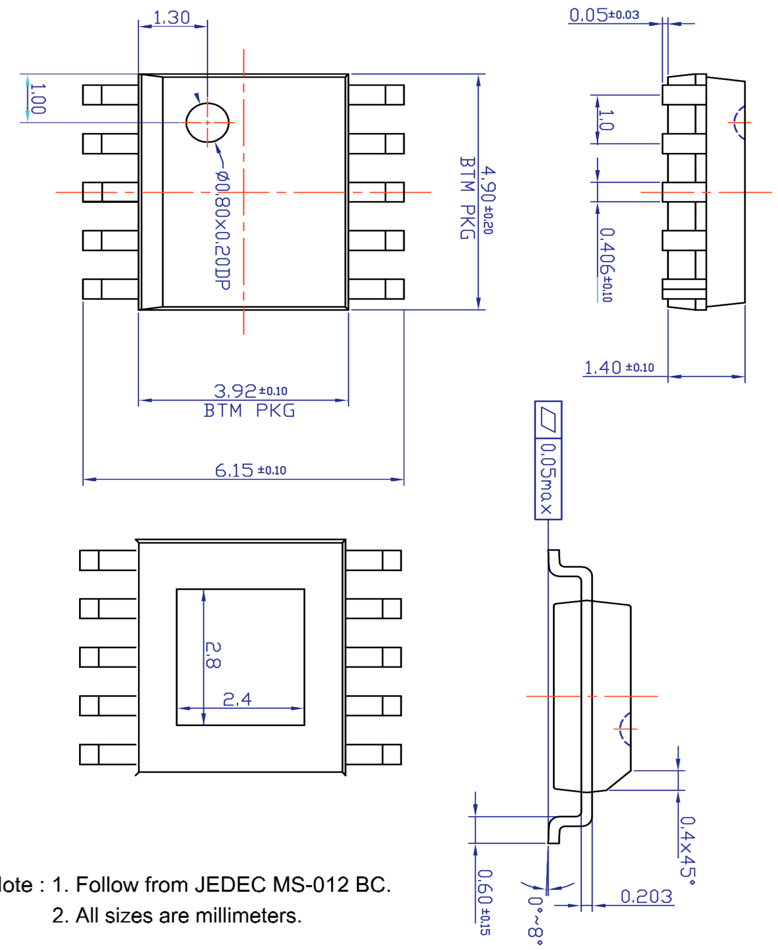
2. The length of the control signal 3# is not limited.

CS83601 E circuit working diagram





Package information: ESOP 10L



Note : 1. Follow from JEDEC MS-012 BC.
2. All sizes are millimeters.